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STEM Stories for STEM Interest and Identity for Girls:
A Classroom-Tested Framework and Prototype

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STEM Stories for STEM Interest and Identity for Girls: A Classroom-Tested Framework and Prototype

by

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Dedication

This work is dedicated to my family, Sean, Austen, Sophia and Alana Ramsey. Together, we live my favorite stories.

Abstract

STEM Stories for STEM Interest and Identity for Girls: A Classroom-Tested Framework and Prototype

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Women and STEM need each other. Women can benefit from stable, well-paying STEM careers. STEM industries can benefit from increased numbers of STEM graduates and more diverse teams. Near-future, STEM-related, ethical challenges will need diverse teams to solve them. But girls in K–12 show less interest and identity with STEM than boys, they take fewer STEM courses, and they pursue STEM careers in lower numbers. This paper explores the use of narrative as pedagogy to increase STEM interest and identity for all students, especially for girls. A prototype STEM Story + Lesson was developed and tested in high school classrooms. The teachers' experiences were analyzed to improve future story curation and lesson development. The STEM Story Framework was created to guide development of STEM Story + Lessons in the future, for classroom use and more detailed research.

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Chapter 1: Challenges and Opportunities for Girls and Women in STEM

"Science is not a boy's game, it's not a girl's game. It's everyone's game. It's about where we are and where we're going.

– Nichelle Nicholas, NASA Ambassador and actress, Lt. Uhura in Star Trek

Over forty years ago, *Star Wars: A New Hope* brought us hologram messages, hovering cars, and the Death Star. Today, our cars still don't hover, but some of them drive themselves. We have seen amazing changes in technology, including the Internet, smart phones, and computer chips thin as a piece of paper embedded in our credit cards. With the promise of ternary computing and machine learning to exponentially increase how computers affect our lives, these are interesting and important times. The country and the world need greater STEM (Science, Technology, Engineering, and Math) literacy, more STEM professionals, and high-level philosophical and ethical leadership. Economies, individuals, and societies will benefit when women are a significant part of this future.

Women and STEM Need Each Other

Economists have predicted that there will be an increasing shortage of STEM workers in the next 20 years and beyond. Changing the Equation presented the following statistics on STEM diversity in the United States in 2015. Industry demand for STEM workers is projected to grow 5% faster than non-STEM jobs between 2014 and 2024. At the same time, more STEM workers are nearing retirement. Also, the white and Asian population that comprises the bulk of the STEM workforce is decreasing as a percentage of the working-age population while populations underrepresented in the STEM workforce (primarily African Americans and Latinos) are increasing in the general population. Given current trends, women are not likely to fill the new STEM jobs, since women's percentage of the STEM workforce is not increasing (Change the Equation, 2015). When these factors are considered as a whole, a national shortage of STEM workers is very likely.

In addition to the economic need for women to fill the STEM jobs, the STEM demand could provide significant opportunity for women to increase their earnings. In 2016, the Institute for Women's Policy Research reported that "women's median earnings are lower than men's in nearly all occupations." The report also found that male-dominated occupations, such as software development, tend to pay more than female-dominated occupations at similar skill levels (Hegewisch & Ellis, 2016). Similarly, the STEM demand could provide leadership opportunities for women earlier in their career. The number of women with graduate degrees who enter organizations at a professional level is not proportionate to their representation at senior and board levels (Frank, 2017). The significant demand in the field creates opportunity for women to make especially significant gains in pay and leadership positions.

Current global challenges are significant, including climate change, energy production, and cyber security. Technology advances will require decisions about philosophical and ethical issues such as cloning, surveillance, increased job automation, and big data. These challenges require that all students are STEM literate, so they can be informed STEM consumers and users. The challenges also require that more diverse people, in greater numbers, choose STEM majors and careers so that key strategies and decisions for technology's future are made by non-monolithic teams that represent technology's users and incorporate multiple perspectives.

If more women pursued and achieved stable and well-paying STEM careers, there would be economic benefits at the individual and national level. Barriers exist, however. Both STEM interest and identity have significant influence on STEM engagement and retention throughout high school, college, and career. Girls' STEM interest has been shown to be lower that boys' STEM interest at the beginning of high school and this difference increases by the end of high school (Sadler et al., 2012). Also, the traditional view of scientists as male still exist in students' minds (Çakmakcı et al., 2011). Media, in the form of comics, novels, newspapers, movies, and more, influence students' images of scientists as male (Çakmakcı et al., 2011). Research on stories in science education, addressed in Chapter 2, suggest that STEM Stories have the potential to address issues of STEM interest and identity, especially for girls and women.

POSITIONALITY

My personal experience gives me a unique perspective on this topic. My first bachelor's degree is in Secondary Education, my second bachelor's degree is in Computer Science. I was raised in a traditional family with strict and often-emphasized gender expectations. I also have a 20-year career in the male-dominated software development field.

I deeply value my computer science degree and software development career. They gave me opportunities for interesting work and financial independence. I had choices that most women of previous generations didn't have, to choose where I lived, what type of work I wanted to do and who (and if) I would marry. It is difficult to imagine my life without these opportunities.

I remember the day, the class, and the steps of the building I was climbing, when I first thought I *might* be able to do Computer Science (a sunny day, Operating Systems and concrete steps with a black, metal hand rail). I remember it the same as I remember historical events, because it changed me a little and changed what I expected to happen next.

I was walking to the class with a familiar sense of dread, that I wouldn't be able to do the work and the professor and other students would discover that I can't really do CS. I remember the weight of this feeling, as if my body was heavier than it needed to be, as if getting up the steps took more effort than it should. I felt this way despite the evidence: I had a CS minor from my first degree; I had taught C Programming, Networks, and Operating Systems at Brazosport College; and I was a senior CS major at The University of Texas.

On that particular sunny day, I wondered if it would be easier to get up the steps without the extra weight. What if I just wasn't worried about it? Maybe I could do the work. Maybe I would even be good at it. Just maybe.

I decided I could be neutral. I would walk into the classroom without an opinion about my abilities either way and just see what happened, as if I was watching someone else and just being curious. This isn't the same as having confidence, but the minor mental shift made a huge difference for me. The shift lifted the weight of doubt and left more energy for the work itself.

A complete exploration of my ideas and feelings about gender, computer science identity, cultural stereotypes, family gender expectations, and the related limitations, realizations and opportunities, are beyond the scope of this paper. I present this small glimpse to provide understanding about my relationship with this research. I believe that strong and limiting gender stereotypes negatively impact people's academic performance and career opportunities, especially for girls in male-dominated fields. When each person can approach their school and work without negative stereotypes, and maybe even with confidence, then people, companies, and economies will benefit.

PURPOSE

The purpose of this project is to review literature on the role of STEM Stories as a pedagogical tool to increase STEM interest and identity for students, especially girls, then use this analysis to develop a prototype STEM Story and Lesson for classroom use. Teachers' feedback from the experience will be used to create a framework to guide development of more STEM Story and Lessons for classroom use and more detailed research. The student STEM interest and identity issues addressed in this paper often also apply to other populations underrepresented in STEM such as African American and Latinx students, and lower SES students. Future research may address similar questions for these populations.

Chapter 2: Story as Pedagogy in Science

"We are, as a species, addicted to story. Even when the body goes to sleep, the mind stays up all night, telling itself stories."

– Jonathan Gottschall

Some say people have been telling stories since they have been able to talk, and maybe even earlier, in grunts, gestures, and cave drawings. The promise and power of story has been known by politicians, priests, and business people for almost as long. It isn't surprising that educators have also looked to story as pedagogy.

STORY AND SCIENCE EDUCATION

Evidence for the power of story has been found across disciplines. With recent advances in brain science, social and physical scientists have begun studying story and how our brains are wired to respond to them (Cron, 2012). Business researchers have shown that using stories with emotional elements are more likely to change minds and lead people to action (Aaker, 2017; Escalas, 2007). Psychologists have found that co-construction of healing stories can serve as therapeutic interventions for patients (Lieblich, McAdams, & Josselson, 2004). Educators have demonstrated that stories can powerfully impact students' attitudes, beliefs, and behaviors (Kauffman & Libby, 2012; Oatley, 1999). Given the broad promise of stories, it is possible that they could impact interest and identity for K–12 students.

For the past ten years, Stephen Klassen, Cathrine Froese Klassen, and others have studied the use of stories in the science classroom. S. Klassen developed a schema for a story in the classroom (S. Klassen, 2007) and C. F. Klassen developed a methodology for science story construction and analysis (C.F. Klassen, 2014). In 2012, a research team created a science lesson based on the story of Nikola Tesla. Students in the class exposed to science stories performed better on assessments one week and eight weeks after the intervention (Hadzigeorgiou et al., 2012). Other researchers have found similar results. For example, research with 7^{th}-grade science students in Turkey found increases in performance for students exposed to science stories (Akarsu, Kariper, & Coskun, 2015).

STORY, INTEREST, AND IDENTITY

In addition to studying the potential for science stories to improve student performance, researchers have studied their potential to increase students' interest in science. Educational interest arises from an emotional response to the learning episode and consists of increased and persistent attention accompanied by the desire to re-engage (Klassen & Klassen, 2014). Science interest is a key factor in students' performance and learning in the subject (Hidi & Harackiewicz, 2000). The issue is a particular concern for girls, because they tend to show less interest in STEM than boys (Tellhed, Backstrom, & Bhorklund, 2017). This is true especially when computer science stereotypes such as social isolation, intense focus on machinery, and inborn brilliance are salient (Cheryan, Master, & Meltzoff, 2015). Research has shown a relationship between students' experiences with science stories and their science interest (Hadzigeorgiou, Klassen, & Klassen, 2012).

Stories also have shown promise in increasing students' science identity. While there are several definitions of identity, this paper considers a person to have a science (or STEM) identity if they recognize themselves as a science person and get recognized that way by others (Farland-Smith, 2009). Some girls believe that science is a domain that belongs to males and that they cannot "do" science (Brickhouse et al., 2000; Farenga & Joyce, 1999). This perception may influence girls' course selection in high school, which can influence later college major and career decisions (AAUW, 1992). Stories show promise related to science and STEM identity. For example, researchers found that, when students see scientists' successes and failures through stories, it helps them identify with scientists (Erten, Kıray, & Şen-Gümüş, 2013). Also, role model exposure, inherent in stories, can have a positive impact on academic sense of belonging for students (Shin, Levy & London, 2016).

LIMITATIONS

While research suggests that science stories can have a meaningful positive impact for students, especially girls, there are a few limitations. The first limitation of the current research is that it is almost exclusively focused on science, with little research for math, engineering, or technology (computer science) disciplines. At the same time, women's underrepresentation in STEM is especially acute in computer science and engineering. It is important to expand the research for these fields. From this point forward in this paper, the topic under discussion is STEM Stories instead of science stories.

The second gap is that current research focuses on the written short story, written specifically for classroom use, such as Klassen's Atlantic Cable story (Klassen S., 2007), while audio and video stories may have advantages. Current trends in science communicators' audio podcasts allow for dramatizations as opposed to narration, which can increase listener emotion and involvement (Rodero, 2012). Video has the advantage of showing female STEM practitioners in action, which may influence girls' STEM identities (Shin, Levy, & London, 2016). Audio and video content have practical advantages as well, since they are typically free of charge and immediately accessible in the Internet-connected classroom. While students might read, listen to, or watch a written, audio, or video story, for simplicity, the remainder of this paper will reference listening to audio stories.

A significant limitation is that existing research is nearly exclusively about historically significant stories of genius science practitioners (Klassen, S., 2009). This is problematic for students' STEM identities. These stories can reinforce the belief that high-level scientific performance requires exceptional inborn ability, which means that students tend to give up before they give themselves a chance to develop their own talents (Dweck, 2000; Hong & Lin-Siegler, 2012). These beliefs are likely to undermine effort when it is most needed—when students struggle in science classes. Students may misperceive their struggle as an indication that they are not good at science and will never succeed in it (Dweck, 2010; Hong & Lin-Siegler, 2012). The belief in the necessity of exceptional scientific talent for science learning hinders efforts to increase the number of students pursuing STEM careers (National Academy of Science, 2005). To more fully realize the potential impact of STEM Stories, contemporary stories of typical practitioners should be considered.

A final limitation is that the majority of the research provides little information about the context of the story within the classroom. S. Klassen defines the Story Driven Contextual Approach (SDCA), which shows how a story combines with student and teacher experience and knowledge to create an updated student understanding, across practical, theoretical, social, historical, and affective contexts (Klassen, S., 2007). This same paper describes a general classroom approach of: 1) students read the written story or the teacher reads the story aloud, 2) a class discussion or investigation, guided by the teacher, and 3) a student final report for assessment purposes. The story would provide connection to previous knowledge and spark student questions, and the discussion would provide active participation with the content.

This approach is better than rudimentary forms of storytelling, for example, the story callout in a textbook that isn't likely to be read. But, it is also minimalist, providing little guidance for what the discussion or investigation should look like. Also, this approach doesn't take advantage of theory or models such as constructivism, 5E instructional model and project-based learning, which are associated with increased student interest and identity. The approach also doesn't provide guidance for how a curriculum developer or teacher should curate stories or design lessons for the classroom.

Chapter 3: A New Approach for Story as Pedagogy in STEM

"Step out of the history that is holding you back. Step into the new story you are willing to create."

– Oprah Winfrey

Given the benefits of more women in STEM careers and the promise stories have shown in science, the effort to develop an updated approach for STEM Stories is valuable. There are many elements from previous research that will remain, as well as changes to incorporate non-science STEM disciplines and to maximize impact on student interest and identity, especially for girls.

CRITICAL PEDAGOGY AND THE STEM STORY

This work is informed by critical pedagogy, which seeks to question the social and historical forces and power structures that dominate education. This theory "aspires to link the practice of schooling to democratic principles of society and to transformative social action in the interest of oppressed communities" (Darder, Baltodano, & Torres, 2003). While stories as STEM pedagogy show promise for student performance, interest, and identity, there are several elements of the current approach that may limit, or even reverse, positive impacts specific to girls.

The current approach to stories as pedagogy relies on historical stories of prominent scientists who made discoveries or inventions directly related to the content being taught. Each STEM story is a synthesis of history and content.

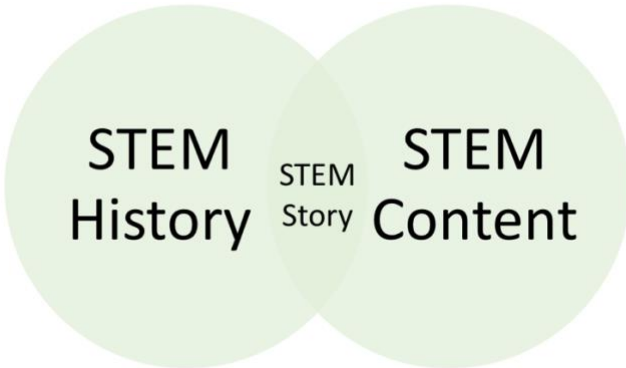

Figure 1. Current STEM Story Elements

Historical stories have the advantage of being formally researched, with time allowing for fuller context and meaning. These stories can also have a more direct connection to the content, since discoveries of historical significance are more likely to relate to core discipline content. Contemporary stories have advantages from an identity perspective, allowing for more stories from historically underrepresented STEM practitioners and topics that tie more closely to student interests, such as music, the environment, or sports. Contemporary stories can also have more cultural relevance, with ties to current events and specific cultures.

A disadvantage of curating stories based on historical significance is that the stories reflect the power structure of the past, which was dominated by men. Men had money, access, and connections for education and careers, making them far more likely to do important work related to contemporary class content. While efforts can be made to find stories about women who have done historically significant work, it is difficult to find stories that took place during times when women weren’t admitted to universities or permitted to have jobs when they were married. The following screen shot shows the results of a Google search for “historical scientists” on December 6, 2017, resulting in 88% male scientists.

Figure 2. Google Search for “historical scientists”

When girls already identify with science less than boys, presenting stories of scientists who are overwhelmingly male is likely to reinforce the stereotype of the male scientist. Girls may avoid STEM because stereotypes signal that they do not belong (Master, Cheryan, & Meltzoff, 2016). There is also a missed opportunity. Exposure to female role models in STEM promote STEM identification for girls (Shin, Levy, & London, 2016; Marx & Ko, 2012). By including contemporary stories as STEM Stories, there is more opportunity to share stories of female STEM practitioners, avoiding the stereotype of the male scientist and improving girls' understanding of their place in science.

Another limitation of historical STEM stories is that scientists who are historically important generally fit the genius stereotype of the scientist. While these stories play a role, evidence suggests that these stories promote a misconception that STEM success is dependent on unique and innate talent inaccessible to most people (Lin-Siegler et al., 2016). Stories of more typical STEM practitioners are more likely to represent science careers as more accessible. Also, students are less likely to identify with a STEM practitioner whom they consider to be very different from themselves. Differences in other historical story elements, such as time, setting, and language, can also make the story more difficult for identity.

UPDATED APPROACH FOR STEM STORIES

This updated approach for STEM Stories includes three changes to STEM Stories for classroom use to better support the potential to increase STEM interest and identity, especially for girls. The first change is to broaden the definition of a STEM Story to include contemporary stories of typical practitioners. This allows for more stories of people who have been historically underrepresented in STEM and has the potential to increase student STEM identity (Shin, Levy, & London, 2016). Contemporary stories can be more easily tied to areas students are already interested in, such as the environment, sports, fashion, or music. This approach has been successful for STEM efforts such as Bootstrap World (http://www.bootstrapworld.org/), which teaches math through video game programming, and Shine for Girls (http://www.shineforgirls.org/), which teaches math through dance. Contemporary stories can incorporate culturally relevant themes and social justice issues, which can provide a path into science for students who feel alienated from traditional school (Emdin, 2010; Laughter & Adams, 2012). This change reduces the impact of the stereotype of the genius STEM practitioner, with fixed, innate abilities and allows for STEM practitioners with whom students will be more likely to identify (Lin-Siegler et al., 2016).

The second change is to include stories that demonstrate STEM practices, adding another layer of richness to the STEM Story and potentially increase students' STEM interest. This change reflects the Next Generation Science Standards' (NGSS) emphasis on teaching STEM content and practices together. "In the real world, science and engineering are always a combination of content and practice" (National Research Council, 2012). Stories that focus on STEM practices are more likely to increase student interest, because students will become familiar with what STEM practitioners do, instead of only understanding the final product of their work. The focus on practices helps student recognize STEM as creative work that deeply impacts the world, instead of as a set of isolated facts (National Research Council, 2012).

The NGSS defines practices for the science and engineering disciplines. The Common Core Math standards define math practices. K12CS, a collaboration of The Association for Computing Machinery, Code.org, and others, defines practices for computer science. The practices follow:

Table 1. STEM Practices by Discipline

Discipline	Reference	Practices
Science	Next Generation Science Standards (National Research Council, 2012)	Asking questions Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations Engaging in argument from evidence Obtaining, evaluating, and communicating information
Technology (Computer Science)	K12 Computer Science Framework (K12 Computer Science Framework Steering Committee, 2016)	Fostering inclusive computing culture Collaborating around computing Recognizing and defining computational problems Developing and using abstractions Creating computational artifacts Testing and refining computational artifacts Communicating about computing
Engineering	Next Generation Science Standards (National Research Council, 2012)	Defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Designing solutions Engaging in argument from evidence Obtaining, evaluating, and communicating information

Table 1. STEM Practices by Discipline (continued)

Discipline	**Reference**	**Practices**
Math	Common Core Math Practices (Coury, 2011)	Making sense of problems and persevere in solving them Reasoning abstractly and quantitatively Constructing viable arguments and critiquing the reasoning of others Modeling with mathematics Using appropriate tools strategically Attending to precision Looking for and make use of structure Looking for and expressing regularity in repeated reasoning

The final change is to provide a framework for a lesson as a companion to the STEM Story, to describe what happens in the classroom *after* the story. The lesson is based on theory, pedagogy, and interest and identity research, similar to STEM Story curation described earlier. The lesson includes guided listening during the story and a small group activity after, to assist students in using their previous knowledge and building their own understanding related to the content. Chapter 5 will describe the lesson in detail. The following diagram illustrates the updated approach's three changes to the STEM Story Elements.

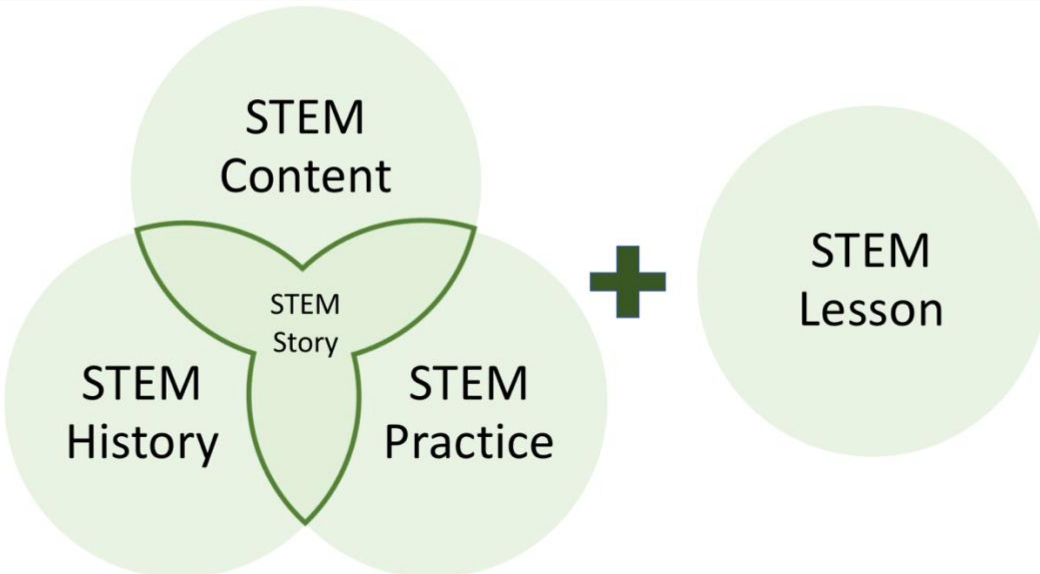

Figure 3. Updated STEM Story Elements

PROTOTYPE STEM STORY + LESSON

This research project required a prototype STEM Story + Lesson. The story titled "Super Cool," from the Radio Lab podcast (Radio Lab, 2017), was selected because: 1) it includes an example of the science practice of engaging in argument from evidence, 2) it includes interviews with female scientists, Virginia Walker of Queen's University and Erin Pettit of the University of Alaska, Fairbanks, and 3) it describes a sense of wonder about science. The story description from the Radio Lab web site follows:

> When we started reporting a fantastic, surreal story about one very cold night, more than 70 years ago, in northern Russia, we had no idea we'd end up thinking about cosmology. Or dropping toy horses in test tubes of water. Or talking about bacteria. Or arguing, for a year. Walter Murch (aka, the Godfather of The Godfather), joined by a team of scientists, leads us on what felt like the magical mystery tour of super cool science.

The podcast tells a traditional story of Malaparte, an Italian journalist, poet, diplomat, soldier, and film director. In 1942, a Milanese newspaper sent him to the Russian and Finnish border during the Nazis' Siege of Leningrad. In the winter, on the shores of Lake Ladoga, Nazis launched bombs into the forest across the lake, starting a forest fire. Hundreds of horses bolted through the flaming forest to the open area of the lake, running into the lake, one after the other. Then the lake froze instantly, entombing the horses, suspended in the water. Malaparte saw a sculpture garden of hundreds of horses' heads above the ice, frozen solid. The sculpture remained for the duration of the winter.

The podcast hosts, Jad Abumrad and Robert Krulwich, are curious about the possibility that this story might be true. Is there a scientific explanation that would support the story? They explore the science behind freezing water and nucleators, interviewing scientists, and freezing a tiny plastic horse in a test tube. They gather evidence and argue the possibilities. Then, they use the role of the nucleator in freezing ice as a metaphor for the consolidation of space matter into solid objects after the Big Bang.

Three figures for the prototype follow: one for each page of the Teacher Lesson Plan and one for the Student Handout.

Teacher Lesson Plan
RadioLab: Super Cool

Objectives		
• Learn characteristics of ice and the freezing process, with an explanation of nucleators such as ice, dust and bacteria. • Understand the idea of a nucleator as an instigator for the creation of the universe. • Practice NGSS science practices of: asking questions, constructing explanations and engaging in argument from evidence.		
Setup		
Before Class	N/A	• Print the Student Handouts. • Obtain computer, tablet or phone with Internet connection and speaker that will reach all students in the room. • Listen to the story and review the lesson to identify links to previous lessons and potential student questions.
Beginning of Class	2 min	• Open a browser on an Internet-connected computer, tablet or phone with a speaker. • Google “RadioLab Super Cool.” Click on the link titled, “Super Cool - RadioLab.” (If the search doesn’t work, you can type in the direct link: http://www.radiolab.org/story/super-cool/.)
Lesson		
Introduction (Engage)	5 min	• Introduce the story: *In this story, two scientists hear an old and tragic story about Russian horses and a frozen lake. They try to figure out what you think really happened and end up learning about a possible end of the universe.* • Compare ideas in the story and objectives of this lesson with those in previous lessons. • Pass out the Student Handouts and introduce the Guided Listening questions. Explain that listening for this information will prepare them for debates later in the lesson.
Story (Explore)	23 min	• Emphasize to the students that this story isn’t a passive listening exercise, that they should think like scientists, question what they hear and come up with their own opinion. • Play the story: start time: 0 minutes, end time: 22 minutes.

Figure 4: Prototype Teacher Lesson Plan, Page 1

Lesson (continued)		
Small Group Activity (Explain)	15 min	• Have the students get into small groups of 3-4 students to complete the Small Group Activity. • Instructions for the students, from the Student Handout: Work together to assign a job to each person: judge, debate pro and debate con. (One job may have two people for groups of four.) The judge will ask the debate pro person to present their case that the story about the Russian horses is true in 3 minutes. The judge will then ask the debate con person for evidence that the story is false in 3 minutes. The judge will then give each person 1 minute to respond to the other's case. Then the judge will declare a winner. • Assist the groups if needed.
Class Discussion (Extend and Evaluate)	15 min	Bring class back together for the following discussion topics that will apply concepts and provide information about what was learned. You can use these questions in a different order, add your own and take out what doesn't fit in the time given. • Ask the students which side won the group debates. Did one side win more often? Were there strong dissenting opinions? Did any groups disagree with the podcast hosts? • Which types of debate arguments were more or less effective? Do these patterns hold in fields outside of science? • Science tells us that water freezes at 32 degrees F, but this story says freezing will happen at different temperatures depending on conditions. Which is true? Why are there two versions of the facts? • What are examples of nucleators and what processes can they initiate? • Did you find yourself "wanting" the story of the Russian horses to be true? Did it change how you listened to the evidence? • What do you imagine a future "phase change" of the cosmos might look like? Wrap up the discussion. Share this link for videos of the lab work described in the story and people's opinion of the folk tale (in the comments): http://www.radiolab.org/story/super-cool/
Total Time	**60 min**	

NOTE: The times specified are a guideline only. The timing should adapt to the students' experiences.

Figure 5: Prototype Teacher Lesson Plan, Page 2

Student Handout
RadioLab: Super Cool

Guided Listening

The RadioLab hosts are known to be curious, like most scientists. What are some of the questions they wondered about during the story?

What evidence was presented to prove the story about the Russian horses?

What evidence was presented to disprove the story about the Russian horses?

Do you believe the story of the Russian horses is true?

Small Group Activity

Get in small groups of 3-4 people. Work together to assign a job to each person: judge, debate pro and debate con. (One job may have two people.) The judge will ask the debate pro person to present their case that the story about the Russian horses is true in 3 minutes. The judge will then ask the debate con person for evidence that the story is false in 3 minutes. The judge will then give each person 1 minute to respond to the other's case. Then the judge will declare a winner.

Figure 6: Prototype Student Handout

Chapter 4: Research Questions, Methods, and Results

Research is formalized curiosity. It is poking and prying with a purpose.

– Zora Neal Hurston

A prototype STEM Story + Lesson was developed based on research. The purpose of this project was to have teachers gain experience with the prototype in the classroom and provide feedback that will lead to improvements. The resulting research- and experience-based framework can then guide the development of STEM Story + Lessons for classroom use and future research.

RESEARCH QUESTIONS

The research addressed two questions: 1) How will experienced STEM teachers' previous experiences with story in the classroom impact the prototype? and 2) How will teachers' experiences with implementing a prototype STEM Story + Lesson with students in the classroom impact the prototype? The research and theoretical perspectives used to develop the framework are important, but teachers' and students' classroom experiences are an essential key to any curriculum-based framework. The framework was developed with the feedback data and analysis as a guide.

METHODS

A qualitative approach was used to gather open-ended insights from the experienced STEM teachers. During the planning phase, the researcher identified the primary contact at a large Texas high school. A cover letter to recruit additional teachers was provided, including a research summary, project structure and timeline and prototype lesson overview. The lead teacher recruited five potential teacher participants and a project orientation was held. The session covered the research proposal and highlights of the preliminary STEM Story + Lesson prototype. Logistics were discussed including preparation and class time commitments. One teacher chose to not participate, because she was a first-year teacher with limited time for optional projects. A second teacher did not participate because his courses were subject to state testing and aggressive improvement goals that prohibited spending class time on optional projects. The remaining four teachers agreed to participate in the project. All of the teachers were STEM teachers (physics, health sciences, and environmental sciences), with between five and 20 years of teaching experience.

The teachers determined which sections of their courses would experience the STEM Story + Lesson prototype. The teachers consistently chose courses that were not tested. Also, the teachers chose to include all sections of a given course, to avoid difficulty with active parents concerned about inconsistent instructional opportunities.

Phase 1 consisted of a focus group with the four participating teachers to review a draft of the STEM Story + Lesson prototype. Notes were taken and analyzed, and the prototype was then updated accordingly. A sketch of the framework was created.

Phase 2 consisted of each teacher using the prototype in one or more classes on their own schedule, then completing open-ended feedback by email or phone. This information was analyzed, and the prototype was updated based on the results. Then the STEM Story Framework was further developed.

RESULTS

Feedback from the Phase 1 focus group confirmed that high-speed Internet, laptop (or other device), and speaker were available in the classrooms. This phase also confirmed that the Guided Listening would be an important element in maintaining students' attention during the audio story and in tying elements of the story to the subsequent group activity. The Phase 1 feedback led to two modifications of the prototype. Objectives were defined in the Teacher Lesson Plan, so the teacher could more quickly evaluate the fit for her classroom and tie the lesson to previous work. Also, timing was added to the lesson items. While student-centered lessons are generally not timed because this limits the students' ability to self-direct their learning, the teachers said a rough guideline would be helpful. A concern was also expressed about the group activity and how it would play out in the classroom, given the specifics of the class and student personalities. The next phase was able to address that question.

Feedback from the classroom implementations of the prototype in Phase 2 led to an update to the framework. Multiple teachers gave the feedback that the 20-minute length of the story was too long to hold the students' attention. A 10-minute maximum length was suggested for a STEM Story. This length would also allow more time for the more interactive activity and discussion elements of the lesson.

Feedback from Phase 2 led to several insights for future research. One teacher with significant experience using audio stories in her classroom suggested that video stories might be more effective. She said that students were more engaged with video and were often not attentive to audio-only stories. Video stories might also have increased impact on identity, when students can see STEM practitioners who look like them (Dasgupta, 2011).

One teacher stated that the second half of the Super Cool story, with a nucleator instigating ice freezing used as a metaphor for the Big Bang and the creation of the universe, was too advanced for his junior and senior high school students. This feedback suggests that careful curation of the STEM Stories will be important to find the stories that are the best fit for high school students based on both content and concept. This also suggests that a tighter connection between the stories and the course content would be an advantage.

The final piece of feedback had the most significant impact on the framework. Multiple teachers felt that, for STEM Stories to be effective in the classroom, they would need to use stories tied more closely to the course standards. This would be an absolute requirement for tested courses and would be preferred for all courses. For teachers to add an optional and non-standard curriculum component, it should have the lowest cost of implementation possible. This would require a collection of stories, one per grading period and tied to course standards. Ideally, the stories would also be tied to the sequence and pacing of a specific curriculum.

LIMITATIONS

One limitation of these results is that research was done with science teachers in science classrooms. Given that the current research is nearly exclusively about science and is lacking in other STEM disciplines, it would have been preferred to complete this research with computer science, engineering, or math teachers and classes. The decision was made to work with the science discipline, because relationships existed with science teachers and efforts to recruit in other disciplines were not successful. A second limitation is that the research did not include qualitative or quantitative data from students. This was due to a limited timeframe and school district IRB restrictions. It is hoped that this will be a topic of future research.

Chapter 5: STEM Story Framework

As an architect, you design for the present, with an awareness of the past, for a future which is essentially unknown.

– Norman Foster

The STEM Story Framework is based on science story as pedagogy research, K–12 pedagogy, this project's research results, and implementation considerations. The framework consists of three major areas of curriculum development: the STEM Story, STEM Story Lesson, and STEM Story Series. A curriculum component based on this framework is called a STEM Story Series.

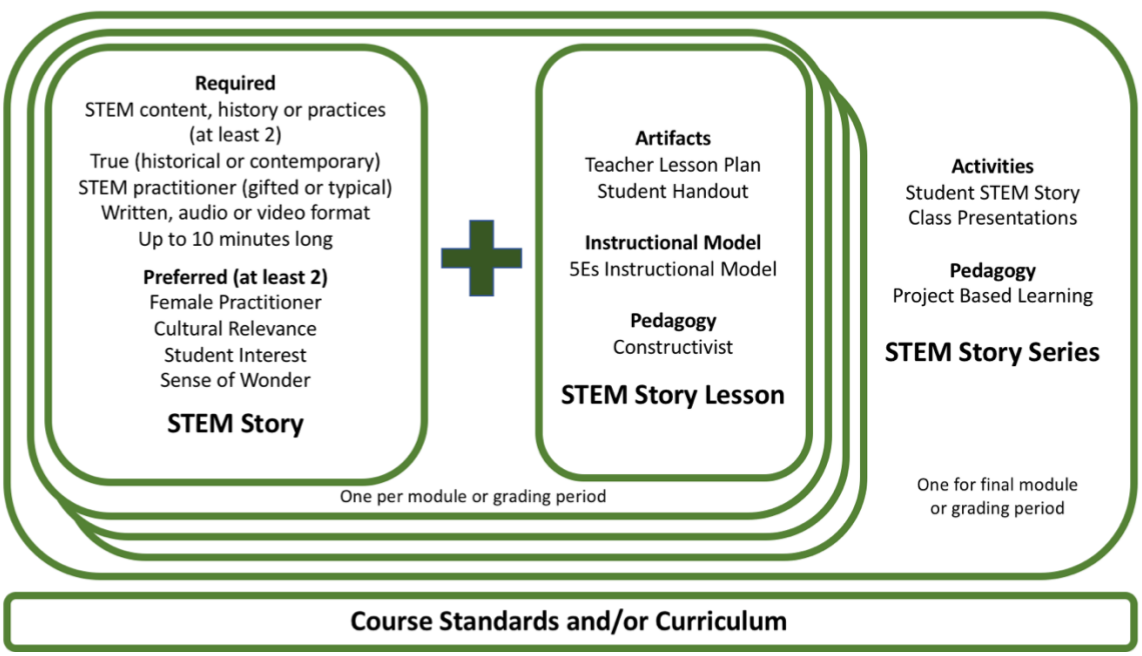

Figure 7. STEM Story Framework

This framework is informed by constructivist theory, that learners construct knowledge based on prior and current experiences. The lesson supporting the STEM Story follows a constructivist pattern that includes incorporating student opinion, active engagement, and reflection.

THE STEM STORY

The STEM Story is the central element of the framework. Story can be defined as a narrative account of events that includes emotional content and sensory details (Simmons, 2002). The STEM Story includes traditional narrative elements such as characters, actions, situations, consequential coherence, and past time (C. F. Klassen, 2014). The STEM Story, in the context of this paper, is the telling of true, personal events of a STEM practitioner that integrates at least two of the following within the narrative: STEM content, history, and/or practice.

Required Elements

The framework defines several characteristics that are required for a STEM Story, most of which were previously addressed in Chapter 3. The story should incorporate two or three of the following: STEM content, history or practices. The story should be true. While some researchers address the use of fiction in the STEM classroom (Manno 2013; Holyoke, 2017; Zhang & Callaghan, 2014), this paper's focus is limited to non-fiction stories. The story can be historical or contemporary, including events, thoughts, and feelings of a recognized or typical STEM practitioner. The story can be in written, audio (such as the Radio Lab, 995 Invisible, Transistor, Hidden Brain, and Story Collider podcasts), or video (such as the Physics Girl YouTube channel) formats. The STEM Story is limited to ten minutes in length. While longer-form stories such as books and movies can also play a role in the classroom (Dickerson, 2015; Berk, 2009), the shorter time supports the pedagogically based lesson and the practical one-hour class time frame.

Preferred Elements

When a story meets the criteria above, it is then evaluated based on preferred characteristics. A story should have at least two of these characteristics. It is not expected, or preferred, that a single story will have most or all of these characteristics. Research suggests that the following story characteristics can increase students' STEM interest and/or identity: female practitioner, cultural relevance, student interest, and sense of wonder. The first three of these were discussed in Chapter 3.

People have long debated the nature of the separation (or not) of science and art, of thought and emotion. Isaac Asimov responded passionately to those who criticized science for sucking beauty out of the world and reducing it to facts and figures, because all that exists beyond what a person can see with his own eye, that science reveals to us, is also beautiful (Asimov, 1979). Einstein said, "The most beautiful thing we can experience is the mysterious. It is the source of all true art and science. He to whom the emotion is a stranger, who can no longer pause to wonder and stand wrapped in awe, is as good as dead – his eyes are closed" (Stedman, 1936). Awe and wonder are considered important in early childhood and primary science education (Wilson, 1993; Munns, 2007), but then we learn the complex world of a physical nature, so various and unfamiliar, we can lose our in-born sense of wonder (Carson, 1998). The last preferred quality for the STEM Story is a sense of wonder, a deeper understanding of STEM in which knowledge is deeply connected to human work and emotions, in which the world is both known and unknowable.

THE STEM STORY LESSON

The STEM Story Lesson is an essential component of the STEM Story Framework. The lesson takes what could be a passive experience of listening to a story and adds the participatory student activity and real-world context. The lesson allows the teacher to make use of STEM Stories with minimal preparation time required. The lesson provides the pedagogical structure for the story, maximizing the classroom learning impact.

The Lesson consists of two artifacts, the Teacher Lesson Plan and the Student Handout, which are both based on the 5Es Instructional Model created by the Biological Sciences Curriculum Committee in 1978. Sustained use of a research-based instructional model helps students learn (Bybee et al., 2006). The 5Es model is built upon previous models with extensive classroom and research experiences, with updates informed by constructivist theory (Bybee et al., 2006). These phases provide a structure for STEM Story Lesson and are embedded within the Teacher Lesson Plan and Student Handout.

Teacher Lesson Plan

The Teacher Lesson Plan provides steps and sequence for the classroom experience and is based on the 5E model.

Table 2. Teacher Lesson Plan Sections and 5E Mapping

Section	5E Phase	Description
Objectives	N/A	States the objectives and connections to course standards.

Table 2. Teacher Lesson Plan Sections and 5E Mapping (continued)

Section	5E Phase	Description
Setup	N/A	Defines the teacher preparation required before class and at the beginning of class.
Introduction	Engage	The teacher introduces the story to pique interest, makes a connection between the story and previous content and student experiences, and hints at the objectives.
Story	Explore	The students read, listen or watch the story while completing the Guided Listening section of the Student Handout. (See next section for more on Guided Listening.)
Small Group Activity	Explain	The students complete the Small Group Activity while the teacher helps each group. (See next section for more on Small Group Activities.)
Class Discussion	Elaborate	The teacher leads the class in sharing results of the Small Group Activity and discussion of related questions that provide context from the outside world. Students answer questions and are encouraged to contribute their experiences and opinions.
	Evaluate	This step is completed simultaneously with Extend. The teacher and students use the class discussion to gather information about how well the objectives have been met.

Student Handout

The Student Handout provides student instructions for the guided listening and small group activity.

Table 3. Student Handout Sections and 5E Mapping

Section	5E Phase	Description
Guided Listening	Explore	The Guided Listening activity asks students to take a few notes or answer a few questions while listening to the story. This is designed to highlight elements of the story that will be important for the Small Group Activity and also to encourage active listening.
Small Group Activity	Explain	Small Group Activities ask students to think more deeply about the content and practices. Students are encouraged to incorporate their ideas and opinions. See the next section for descriptions of Small Group Activity types.

Small Group Activity

The Small Group Activity is a key component of the STEM Story Framework, so will be addressed in more detail. The Small Group Activity allows students to actively engage with the content, to know it and work with it within the context of other ideas and purposes. This segment provides roles for each student, allowing each student to participate and minimize the impact of dominant students. The activities are meant to be fun, allowing students to interact with the content, incorporating their own ideas and opinions.

Table 4. Small Group Activity Types

Type	Roles	Task (based on specified topic related to the STEM Story)
Debate	Pro Debater, Con Debater, Researcher, Judge	Perform debate with three-minute initial arguments and one-minute responses, then the judge declares a winner.
Pro and Con Editorials	Pro Writer, Con Writer, Editor, Cartoonist	Write one pro and one con, one-paragraph editorials and one editorial cartoon.
News Story	Writer, Researcher, Editor, Story Subject	Write a two-paragraph news story given the facts and input from a subject of the story (victim, instigator, or other).
Extreme Blog Posts	Pro Writer, Pro Ad Salesperson, Con Writer, Con Ad Salesperson	Write one pro and one con, one-paragraph blog post, selecting only the facts that support an extreme viewpoint and considering click and share demands of the blog salespeople.
Children's Story	Author, Illustrator, Editor	Write a simple version of the story in a three-page story book, with sketches, for third graders.
Speech	Speaker, Speech Writer, Editor	Write a speech for a specific audience.
Web Page	Designer, Writer, Editor	Create a web page (digitally or on paper).
Podcast	Narrator, Recorder, Content Editor	Create an audio file explaining the content to a specific audience using actual or fictional interviews.

THE STEM STORY LESSON AND CONSTRUCTIVISM

The STEM Story Framework is informed by constructivist pedagogy and heavily influenced by John Dewey. Constructivist pedagogy recognizes that students create meaning through experiences. This method typically involves problem solving, learning in multiple contexts, making connections with existing knowledge, and activities anchored in students' life context (Imel, 2000). Several constructivist qualities are embedded in the framework and included within the STEM Story Lesson.

Table 5. The STEM Story Lesson and Constructivism

Constructivist Quality	Description	Framework Component
Active	Students should actively construct meaning and not remain passive vessels receiving fixed knowledge.	The students complete the Guided Listening in connection to the more passive activity of listening to the story. The Small Group Activity asks students to actively engage with the content.
Authentic	The learning is anchored in realistic terms.	The STEM Story is true. The Small Group Activity is based on real-world roles and activities. The Class Discussion includes connection to current and culturally relevant issues.

Table 5. The STEM Story Lesson and Constructivism (continued)

Constructivist Quality	**Description**	**Framework Component**
Contextual	Provides connection to the real world and to students' interests and experiences.	The story of a STEM practitioner sets the STEM content within the real world. The Small Group Activity can present a related and realistic problem to be solved while students play roles consistent with real-world work teams. The Class Discussion connects the story and content with current issues and events, and student interests.
Student Interest	Connects content to subjects that students are already interested in such as music or video games.	The STEM Story can reflect the use of STEM in a context that students are already interested in, to show students STEM applications in the real world.
Culturally Relevant	Connect content to students' ancestral and contemporary cultures.	The story selection can reflect diverse STEM practitioners and issues important to different cultures. Small Group Activity and Class Discussions incorporate cultural elements.
Reflective	Students think critically about their learning experience to improve learning.	The Small Group Activity and Class Discussion encourage peer review of student understanding and ideas.
Social	Most learning doesn't happen in isolation; students gain experience learning with others.	The Small Group Activity asks students to interact with each other, based on roles, and work toward a common goal.

The STEM Story Series

The STEM Story Series is the final component of the STEM Story Framework and it has three purposes. The series ties together a collection of stories and lessons that match existing course standards. In some cases, the collection may also match the sequence and pacing of an associated course curriculum. This reduces the cost of implementation for teachers and maximizes the impact for students. The series also provides the final component of the framework, which is based on the students' own STEM-related stories. The students are asked to write a five-minute true, personal story, related to an experience of their own with STEM practices. The class will then plan and produce a performance of selected student STEM Stories for an audience.

The STEM Story Series and Project-Based Learning

The STEM Story Framework incorporates several elements of the Buck Institute's Project Based Learning (PBL) Gold Standard. (Note that some of these elements overlap with the 5Es.) PBL is an example of constructivist pedagogy as described in the previous section. This final module in the series asks the students to see themselves as STEM practitioners and to fully engage with and explore what that means to them.

Table 6. The STEM Story Series and Project-Based Learning

PBL Element	**Framework Implementation**
Authenticity	The student stories are personal and true.
Student Voice and Choice	Each student chooses the story to share and students learn from each other's stories.
Reflection	The students are asked to reflect on their own work as STEM practitioners, choose, and share a STEM experience that is meaningful to them.
Critique and Revision	The student story development follows a traditional writing method with drafts, peer reviews, and edits.
Public Product	The students will perform their stories. The students will produce the story presentations for an audience.

Chapter 6: Conclusion

"Life can only be understood backwards; but it must be lived forwards."

— *Søren Kierkegaard*

The promise of STEM Stories from educational and equity perspectives warrants additional efforts to understand the potential effects of story-based curriculum components. This thesis proposes development of a STEM Story Series based on the STEM Story Framework, then using the series for an experimental classroom intervention. As research progresses, additional topics could be studied, including: When considering "student interest," what topics already have student interest? Which Small Group Activities lead to the highest increases in student interest and identity? Which story format—written, audio, or video—is most effective? A key topic for investigation is how to fund and scale the development of STEM Story Series, so they are available to teachers and actively implemented.

When my young girls see someone smoking in public, they gasp and exclaim, "WHAT…IS…THAT?", as if this person was completely naked. My hope is that, in the future, if they were to walk into an office and see an all-male team gathered around a computer, they would also gasp and exclaim. It just wouldn't seem normal. My girls would be part of "normal" and these normal teams would build our future together.

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